Definitions

(1) Steady Flow:

_The flow in which the adjacent layers of liquid slide over each other and the particles of the liquid follow continuous smooth paths called stream lines.

(2) Turbulent flow:

_When the speed of flow of liquid exceeds certain limit, the speed and direction of liquid passing any point vary with time forming vertices.

Conditions of steady flow:

a) Liquid fills tube completely.
b) Rate of flow of liquid is constant along the path.
c) The flow is non viscous.
d) There is no vortex motion.
e) Velocity of liquid at point is constant and does not change with time.

(3) Stream lines:

The path that particles of the liquid flows during its steady flow.

(4) Volume flow rate: ($Q_v = A\ v$)

The volume of liquid flows through certain area per unit time.

(5) Mass flow rate: ($Q_m = \rho\ A\ v$)

The mass of liquid flows through certain area per unit time.

(6) Continuity equation:

The velocity of flow of liquid is inversely proportional to the cross sectional area of the tube in which it flows.($A_1v_1 = A_2v_2$).

(7) Viscosity: The property of fluids due to friction forces between their layers which resist the motion of bodies inside fluids.

N.B. Coefficient of viscosity depends on:

1) kind of liquid 2)Temperature

(8) Coefficient of viscosity: The tangential force acts on unit area of liquid which produces unit change in velocity between two layers separated by unit normal distance.

(9) Properties of stream lines:

i. They never intersect.
ii. The tangent to it at any point represents direction of velocity of particles of liquid at that point.
iii. The number of stream lines crossing perpendicularly through a unit area surrounding a point (density of stream lines) expresses the velocity of flow of liquid at that point.

Give the reasons for:

1) **The velocity of blood flow in capillaries is less than that in major artery.**
 Because the total area of all blood capillaries is larger than the area of the major artery and since from continuity equation($V \alpha 1/A$)the velocity blood in capillaries is smaller than in the major artery.
2) **Fire hoses are equipped with narrow tips**.
 According to the continuity equation, the velocity of flow is inversely proportional to the cross sectional area ($V \alpha 1/A$)so narrow tips give high velocity of water flow so it can reach far distances.
3) **High viscous lubricants should be used in the lubrication process of moving parts of machines while water is not used.**
   I. High viscous liquids have the ability to adhere with the moving parts so reduce the heat generated by friction &protect the machine parts from corrosion.
   II. If we use water which has low viscosity in lubrication process it will rapidly flow away from the machine parts, as a result of the week adhesive forces during its motion which leads to corrosion of the machine parts.
4) **To save fuel the, speed of the cars should not exceed a certain limit.**
   I. At low speeds the resistance of air (due to its viscosity)to a moving car is directly prop. to the speed of the car until a certain limit, called critical speed.
   II. At speed higher than critical speed the resistance of air is directly proportional to the square of the speed which lead to more consumption of fuel, therefore we can save fuel by moving at speed not more than the critical speed.
5) **In medicine the sedimentation rate test is used to know the volume of red blood corpuscles.**
   The sedimentation rate (speed of falling of red blood cells in plasma)
   α square of the radius. Since by knowing sedimentation rate we can know the volume (normal or not):
   (a) in rheumatic fever R.B.C's. adhere, their volumes increase sedimentation rate increases.
   (b) in anemia R.B.C's. break, their volumes decrease, sedimentation rate decreases.
6) **The streamlines are crowded at height speeds and they are far from each other at low speeds.**
   Because the speed of flow of liquid is inversely proportional to the cross-sectional area, so that at a high velocity the cross sectional area is small and that means that the lines of flow are near to each other, and vice versa.

Solved problem

Example (1): Water flows in a horizontal pipe by constant rate $0.012 m^3/min$. Calculate the velocity of water inside the pipe if its cross-sectional area is $1 cm^2$.

Solution

$$Q_V = \frac{Volume}{Time} = \frac{0.012}{60} = 2 \times 10^{-4} m^3/sec \qquad V_{ol}\ (m^3)$$

since $Q_V = A.v.$

$2 \times 10^{-4} = 1 \times 10^{-4} \times v$

$v = 2$ m/sec.

Example (2): Water flows through a rubber tube of diameter 2.4 cm with velocity 6m/sec. find the diameter of the narrow open if the velocity of water is 34.56 m / sec.

Solution

$A_1 v_1 = A_2 v_2$

$\pi r_1^2 \times v_1 = \pi r_2^2 \times v_2$

$(0.012)^2 \times 6 = r_2^2 \times 34.56$

$r_2^2 = 25 \times 10^{-6}$, $r_2 = 5 \times 10^{-3}$ m

Diameter $= 2 \times 5 \times 10^{-3} = 10 \times 10^{-3} = 10^{-2}$ m=10cm

Example (3): An artery of radius 0.35 is divided to 80 capillaries (each of radius 0.1cm), find the velocity of blood in each capillary , if the velocity of blood in artery is 0.044 m / sec.

Solution

A1 v1 = n A2 v2

π r12 ×v1 = n × π r22 ×v2

(0.0035)2 × 0.044 = 80 × (0.001)2 × v2

v2 = 0.00674 m/sec.

Example (4): A tube of cross-sectional area $10cm^2$ at a certain point (A) and $2cm^2$ at another point (B). If the velocity of water at (A) is 12m/sec.
Calculate a) The velocity of water at point (B).
b) The volume and the mass of water which flows in the tube in one minute, ($\rho w = 1000kg/m3$).

Solution

a) $A_1 v_1 = A_2 v_2$

$10 \times 10^{-4} \times 12 = 2 \times 10^{-4} \times v_2$

$v2 = 60m/sec.$

b) $Q_v = A_1 v_1 = A_2 v_2$

$= 10 \times 10\text{-}4 \times 12 = 12 \times 10\text{-}3\ m3/sec.$

$V(volume) = Q_v \times t = 12 \times 10\text{-}3 \times 60 = 72 \times 10\text{-}2\ m^3$

$m = \rho V = 1000 \times 72 \times 10\text{-}2 = 720kg.$

Example (5): A tube of cross-sectional area $4cm^2$ feeds a field with water. Water flows inside it with velocity 10m/sec. It ends by 100 holes (spore). Each of area $1mm^2$. Calculate the velocity of flow of water in each hole (spore).

Solution

$A_1 V_1 = n A_2 V_2$

$4 \times 10^{-4} \times 10 = 100 \times 1 \times 10\text{-}6 \times V_2$

$V_2 = 40$ m/sec.

Example (6): Two metallic plates each of area 10^{-2} m^2 isolated by a layer of liquid of thickness 2mm. If a force of 2.5N affected on the first plate, find its velocity. (η_{vs} of the liquid = 4kg/m sec)

Solution

$$\eta_{Vs} = \frac{F\,d}{AV}$$

$$V = \frac{F\,d}{A\eta_{Vs}} = \frac{2.5\times2\times10^{-3}}{4\times10^{-2}} = 0.125m/s$$

Definitions:

1. **Boyle's law**:
   The volume of certain mass of gas is inversely prop. to its pressure at constant temperature.
   Or: At constant temperature, the product ($P.V_{ol}$)of any given mass of gas is constant.
2. **Volume expansion coefficient of gas at constant pressure:**
   The increase in volume at constant pressure per unit volume at 0^oC for 1^oC rise in temperature.
3. **Charle's law**:
   At constant pressure, the volume of a certain mass of gas increases by ($^1/_{273}$)of its volume at 0^oC for each one degree rise in temperature. or: At constant pressure, the volume of a certain mass is directly prop. to its temperature on Kelvin scale.
1. **Coefficient of pressure at constant volume**:
   The increase in pressure of gas under constant volume per unit pressure at 0^oC for one degree (1^oC)rise in temperature.
2. P**ressure law:**
   At constant volume the pressure of certain mass of gas increases by 1/273 of its pressure at 0^oC for each one degree rise in temperature. Or: At constant volume the pressure of certain mass of gas is directly prop. to its temp. on Kelvin scale.
3. **Zero Kelvin (or absolute zero):**
   The temperature at which the volume of gas vanishes at constant pressure. Or: The temperature at which the pressure of gas vanishes at constant volume.

Give reasons for:

1. **In Jolly's experiment the air enclosed inside the glass bulb must be dry.**
   This to to avoid water vapor pressure because any small droplet changes to large amount of vapor o high pressure when it is heated.
2. **In Charle's experiment the ratio between two volumes of air at 0^oC and at 100^oC is the same ratio between their length at the same temperature.**
   Because the tube containing air has uniform cross sectional area.
3. **Filling 1/7 of the volume of container in Jolly's apparatus by mercury.**
   To compensate the expansion of the container volume to keep the volume of gas inside the container constant.
4. **In Jolly's apparatus, capillary tube is used to connect the bulb with the manometer**.
   To decrease the volume of gas outside the bulb which it is not heated
5. **Coefficient of volume expansion of all gases is constant at constant pressure.**
   Because at constant pressure equal volumes of different gases expand equally when heated through the same interval of temperature.
6. **The momentum of a gas particle before collision = its momentum after collision.**
   Because the gas particles are elastic spheres and they collide with each other and with the walls of container elastic collision.
7. **The absolute zero is the temperature at which the kinetic energy of gas molecules vanishes.**

Because the K.E. of the gas molecules at absolute zero is zero according to the relation $\frac{1}{2} m v^2 = \frac{3}{2} K T$.

8. **The velocity of gas molecule is constant although they collide with one another.**
   This is due to the elastic collisions.
9. **Pressure increases when temperature increases at constant volume**. Because when temp. increases, rms speed increases ($V \alpha \sqrt{T}$) and the rate of collision increases, so the pressure of gas increases.

(1) Boyle's law

It is the relation between the volume of gas and its pressure at constant temperature.

Boyle's law: The volume of fixed mass of gas is inversely proportional to the pressure at constant temperature.

$$V_{ol} \propto \frac{1}{P} \quad (at\ constant\ T)$$

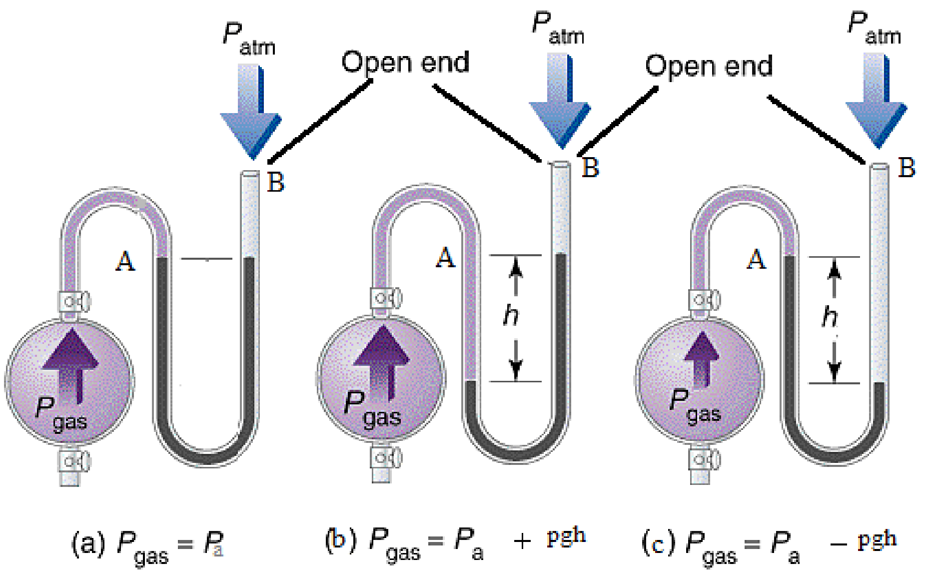


Fig (6-2)

<u>Exp.1: To verify Boyle's law</u>:

- Open the tap T (Fig (6 – 2a)) and raise the reservoir B till the burette is about half full of dry air and the mercury levels are the same in both sides.
- Close the tap T and measure the volume of the enclosed air $(V_{ol})_1$ and its pressure P_1 where, $P_1 = P_a$.
- The reservoir (B) is raised a few centimeters, measure the volume of the enclosed air V_2 and its pressure P_2 where

  $P_2 = P_a + h$ cm Hg

  or $P_2 = P_a + \rho g h$ N/m^2
- Repeat the previous step by raising the reservoir (B) another suitable distance, and measure V_3 and P_3.
- The reservoir (B) is then lowered until the mercury level in (B) becomes lower than that in (A), measure the volume $(V_{ol})_4$ and the pressure P_4 where, $P_4 = P_a - h$ cm-Hg or $P_4 = P_a - \rho g h$ N/m^2(Fig (6-2b)).
- Repeat the previous step one more by lowering (B) another suitable distance and measure V_5 and P_5.
- Draw a graph between (V_{ol}) at y-axis and 1/p at x-axes a straight line is obtained.
- Or draw a graph between (V_{ol}) at y-axis and (P) at x-axes a curvet line is obtained.

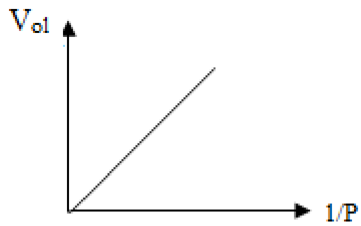


Fig (6-3)

- These indicate that, at constant temperature

$$V_{ol} \propto \frac{1}{P}$$

The mathematical formula for Boyle's law

$$\because V_{ol} = \frac{Constant}{P} \qquad \therefore PV_{ol} = constant$$

or $P_1 V_{ol1} = P_2 V_{ol2} = constant$

Fig (6-3)

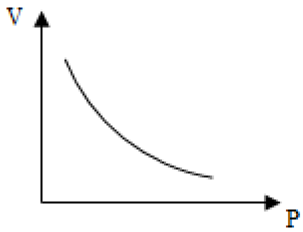


Fig (6-4)

The effect of temperature on the volume of gas at constant pressure:

Exp. 2: To show that the same volume of different gases at constant pressure expands by the same value:

- Submerge two flasks which contain two different gases such as (CO_2), (O_2) in a vessel filled with water as shown in Fig(6 – 5).
- Pour hot water into the vessel and notice the distance moved by the mercury thread in both.

Observation:
The distances moved by the mercury threads in both are equal.

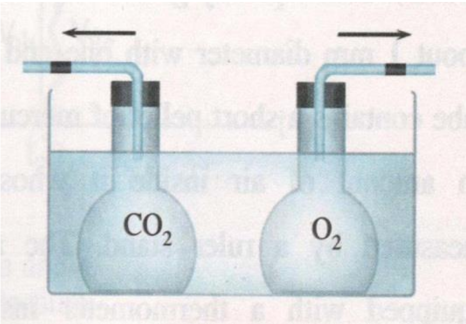


Fig (6-5)

Conclusion:
- Equal volumes of different gases expand equally when heated through the same interval of temperature.
- In addition, they have the same volume coefficient at constant pressure.

The volume expansion coefficient of gas at constant pressure (α_v): It is the increases in volume of the gas per unit volume at 0 ^{o}C for 1^{o}C rise in temperature at constant pressure.

If the initial volume of the gas is $(V_{ol})_{0^oC}$ at 0 ^{o}C, and $\triangle V_{ol}$ is the volume change due to the change in temperature by $\triangle$ T,

$$\therefore \triangle V_{ol} \propto (V_{ol})_{0^oC}, \quad \triangle V_{ol} \propto \triangle T$$

$$\therefore \triangle V_{ol} \propto (V_{ol})_{0^oC} \triangle T$$

$$\therefore \triangle V_{ol} = \alpha_V (V_{ol})_{0^oC} \triangle T$$

$$\boxed{\alpha_V = \frac{\triangle V_{ol}}{(V_{ol})_{0^oC} \triangle T}}$$

<u>Exp. 3: To calculate the volume expansion coefficient of a gas at constant pressure (To verify Charle's law)</u>:

- Use the apparatus shown in Fig (6–6).
- The glass envelope is packed with crushed ice and water. It is then left until the air inside the glass tube reaches 0^oC.
- Measure the length of the enclosed air, which is proportional to its volume (V).
- The ice and water are removed from the glass envelope and steam is passed in through the top and out at the bottom.
- When the temperature of air becomes 100^oC, measure the length of enclosed air which is taken as $(V_{ol})_{100}$

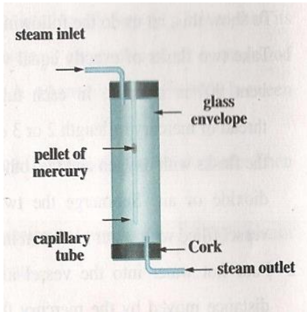


Fig (6-6)

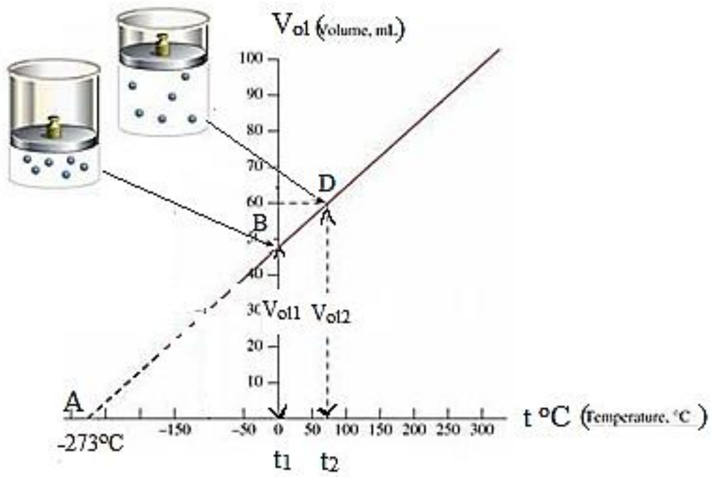


Fig (6-7)

- When the temperature of air becomes 100^oC measure the length of the enclosed air which is taken as $(V_{ol})_{100}$
- Determine the volume coefficient of air at const. pressure by using the relation:

$$\alpha_V = \frac{(V_{ol})_{100^oC} - (V_{ol})_{0^oC}}{(V_{ol})_{0^oC} \times 100^oC}$$

- The value of (α_V) is obtained experimentally for all gases is $^1/_{273}$ of its volume at 0^oc per each degree Kelvin rise in temperature at constant pressure.
- Since equal volumes of different gases expand equally at constant pressure when heated through the same interval of temperature, the volume expansion coefficient of all gases have the same value. This result was formulated by Charle as Charle's law.

Give reason: The volumetric expansion of all gases under constant pressure is constant.
This is because equal volumes of different gases expand equally when heated through the same interval of temperature at constant pressure.

Charle's Law: The volume of a given mass of gas kept at constant pressure, expands by $^{1}/_{273}$ of its volume at $0^{o}c$ per each degree Kelvin rise in temperature. This value is the same for all gases.

The effect of temperature on the pressure of gas at constant volume:

Exp.4: To investigate the pressure of different gases at constant volume increases by the same value:

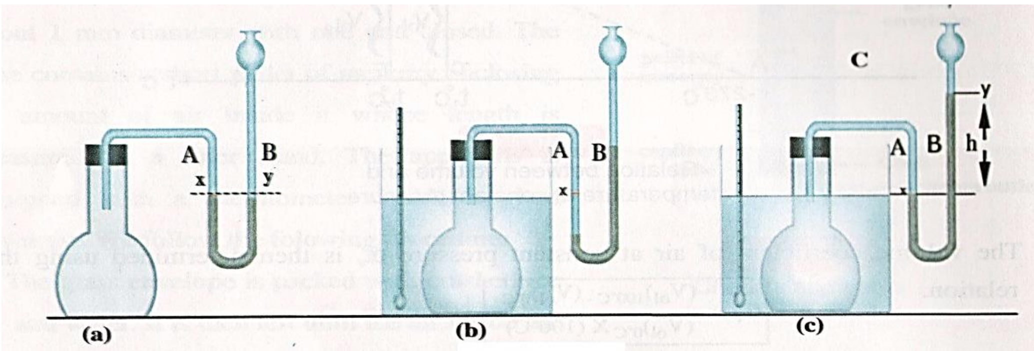


Fig (6-8)

- Use the apparatus shown in Fig (6-8).
- Determine the temperature of the enclosed air ($t^{o}c$).
- Submerge the flask in a vessel containing hot water at $t^{o}c$, the level of mercury lowers in branch (A) and rises in branch (B).
- Pour mercury in the funnel C (Fig(6-8c)) till mercury level returns to (A) (the volume s const.).
- Measure the difference in height between the levels of mercury in the u-shaped tube (h) cm. $P \propto t$
- Repeat the exp. using different gases we find that, at const. volume the pressure of a given mass of gas increases by temperature.
- At constant volume, the pressure of gases increases equally when heated through the same interval of temperature.

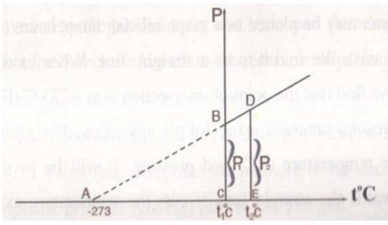
(They have the same pressure coefficient at constant volume).

The pressure expansion coefficient of gas at constant volume (β_p): It is the increase in pressure per unit pressure at $0^{o}C$ for $1^{o}C$ rise in temperature. It is found to be the same for all gases.

Experimentally it was found that the increase in gas pressure is directly proportional to the initial pressure at 0°C (P_o) as well as the raise in the temperature (Δt), $\Delta P \propto P_o$, $\Delta P \propto \Delta t$

$\Delta P \propto P_o.\Delta t$, $\Delta P = \beta_p . P_o . \Delta t$

$$\boxed{\beta_p = \frac{\Delta P}{P_0 \Delta t} = \frac{P_t - P_0}{P_0 \Delta t}}$$



Fig(6 – 9)

<u>Exp, 5: To measure the pressure coefficient of gas at const. volume (to verify pressure law) Jolly's exp.</u>

- Use the apparatus as shown in Fig (6 - 10).
- Insert in the glass bulb(a) 1/7 of its volume mercury to compensate the increase in its volume when heated, so the volume of the remaining part is still constant.
- Adjust the leveling of the mercury in the branch (c) till it rises to a certain mark(x) in the other branch.
- The bulb to 100°C, adjust the reservoir (c) till the mercury level returns to the fixed mark (x), measure the difference in height (h cm) then measure the pressure of the enclosed air.

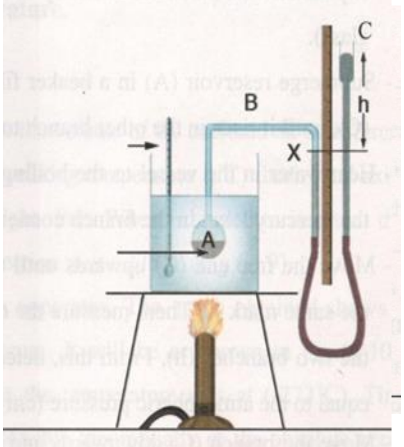


Fig (6 -10)

$$P_{100} = Pa + h \text{ cm.Hg.}$$

- Repeat the previous step by cooling the bulb to 0°C and measure the pressure of the enclosed air (P_o).

$$P_o = Pa - h \text{ cm.Hg}$$

- Use this relation to find the pressure coefficient of gas at constant volume (β_p).

$$\boxed{\beta_P = \frac{P_{100^oC} - P_{0^oC}}{P_{0^oC} \times 100^oC}}$$

The value of (β_p) obtained experimentally is $^1/_{273}$ per unit degree rise in temperature. Moreover, same value is obtained for all gases. From these results we conclude the pressure law of gases.

The pressure law: The pressure of a given mass of any gas changes by $^1/_{273}$ of its pressure at 0^oC for every 1^oC change of temperature at constant volume.

Kelvin Scale:

The relation between the temperature on Celsius scale and on Kelvin scale:

$$t^oK = t^oC + 273$$

The absolute zero: (^{o}k)

The temperature at which the volume of the gas vanishes theoretically at constant pressure.

OR: The temperature at which the pressure of the gas vanishes theoretically at const. volume.

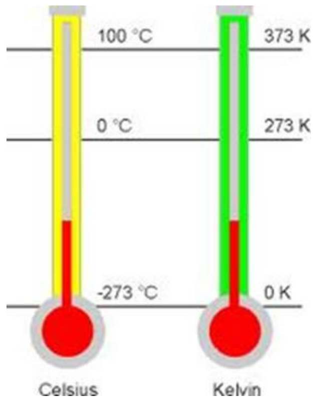


Fig (6 -11)

Other ways of expressing Charle's law and pressure law:

In Charle's exp.

Find the volume of gas at different temp. plot a graph between the volume (V_{ol}) at (y – axis)and temp. at(x – axis) a straight line is obtained which cuts the temp. axis at (– 273°c)

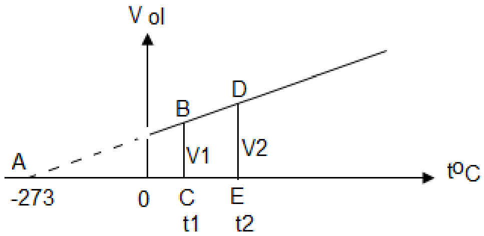


Fig.(6 – 12)

The two triangles ABC and ADE are similar:

BC / AC=DE/AE

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}, \frac{V_1}{V_2} = \frac{T_1}{T_2}$$

Therefore, V/T = const.

V = const. × T

V α T at const. P

Charle's law:

At const. pressure, the volume of a fixed mass of gas is directly prop. to its temp. on k – scale (absolute temp.).

In jolly's exp.

Find the pressure of gas at different temp. plot a graph between the pressure (p) at (y–axis)and temp. at(x–axes) a straight line is obtained which cuts the temp. axis at(–273°c).

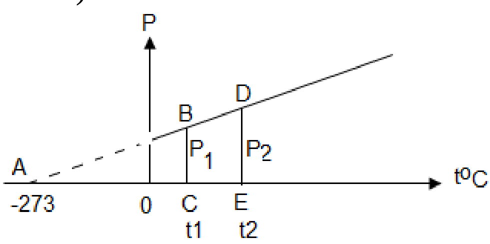


Fig.(6 – 13)

The two triangles ABC and ADE are similar:

BC / AC=DE/AE

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}, \frac{P_1}{P_2} = \frac{T_1}{T_2}$$

Therefore, P/T= const.

P = const. × T

P α T at const. V

Pressure law:

At const. volume the pressure of a fixed mass of gas is directly prop. to its temp. on k – scale (absolute temp.).

The general gas law

From Boyel's law:

$V_{ol} \propto \frac{1}{P}$ (at const. T)

From Charle's law : $V_{ol} \propto T$ (at const. P)

Therefore :-

$$V_{ol} \propto \frac{T}{P}$$

From which:-

$$V_{ol} = \text{constant} \times \frac{T}{P}$$

$\frac{PV_{ol}}{T} = \text{constant}$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Solved problem

Example (1): Boyle's law

Amount of gas of volume 300 cm^3 under pressure 75cm.Hg Find its volume if its pressure becomes 100 cm.Hg at constant temperature.

Solution

$$P_1 V_{ol1} = P_2 V_{ol2}$$
$$75 \times 300 = 100 \times V_2,$$
$$V_2 = 225 \text{ cm}^3.$$

Example (2):

In an experiment to determine the pressure expansion coefficient at constant volume, the pressure of the gas increases about the atm. pressure by 4 cm Hg, 33.6 cm Hg at 0°C, 100°C respectively. Calculate the pressure expansion coefficient at constant volume, If the apparatus is placed in a room, then the pressure of the gas increased a bout atm. pressure by 12.4 cm. Hg. Calculate the temperature of the room (P_a = 76cm. Hg).

Solution: $P_0 = 76 + 4 = 80$ cm. Hg

$P_{100} = 76 + 33.6 = 109.6$ cm. Hg

$$\beta_p = \frac{P_{100} - P_0}{P_0 \times 100^oC} = \frac{109.6 - 80}{80 \times 100} = 0.0037 \text{ C}^{-1}$$

$\beta_p = \frac{\Delta P}{P_0 \Delta t}$,

$$0.0037 = \frac{(76 + 12.4) - 80}{80 \times t}$$

t = 28.4°C

Example (3): Boyle's law

Amount of gas of volume 600 cm^3, find its volume if its pressure decreases to quarter at constant temperature.

Solution

$$P_1 V_{ol1} = P_2 V_{ol2}$$
$$P_1 \times 600 = ¾ P_1 \times V_2$$
$$V_2 = 800 \text{ cm}^3.$$

Example (4):

A capillary tube contains amount of air is trapped by mercury droplet, the length of air column at melting point of ice is 10.92 cm, and the length of air column at 100°c is 14.92 cm. Calculate the volume expansion coefficient of air at constant pressure.

Solution

$$\alpha_V = \frac{(V_{ol})_{100^oC} - (V_{ol})_{0^oC}}{(V_{ol})_{0^oC} \times 100^oC} = \frac{14.92 - 10.92}{10.92 \times 100} = 1/273\ \mathrm{k}^{-1}$$

Example (5):

Amount of gas of volume 15 liter at 17°c, and pressur72cm.Hg, its temperature increased to 27°C, and its pressure to 76 cm-Hg then its volume became 14.7 liter. Calculate:

a) Volume expansion coefficient (α_V) at constant pressure.
b) Pressure expansion coefficient (β_P) at constant volume.

Solution

$V_{ol.1} = 15L$, $P_1 = 72cm.Hg$, $T_1 = 17+273 = 290^ok$
$V_{ol.2} = 14.7L$, $P_2 = 76cm.Hg$, $T_2 = 27+273 = 300^ok$

a) We must calculate ($V_{ol0.}$) at ($T_o = 0^oC$) and fix the pressure at 72cm-Hg. From Charle's law:

$$\frac{V_{ol1}}{V_{ol0}} = \frac{T_1}{T_0}, \quad \frac{15}{V_{ol0}} = \frac{290}{273}, \quad V'_{ol.0} = 14.12 \text{ liter}$$

$$\alpha_V = \frac{\Delta V_{ol}}{V_{olo} \times \Delta T} = \frac{V_{ol1} - V_{ol0}}{V_{olo} \times (t_1 - t_0)} = \frac{15 - 14.12}{14.12 \times (290 - 273)}$$
$$= 3.66 \times 10^{-3} C^{-1}$$

b) The same for β_p

we must calculate (P_o)at ($T_o = o^oc$) and fix the volume at 15L.

From pressure's law:

$$\frac{P_1}{P_0} = \frac{T_1}{T_0}, \quad \frac{72}{P_0} = \frac{290}{273}, \quad P_o = 67.78 cm.Hg.$$

$P_1 - P_o$

Therefore

$$\beta_p = \frac{P_1 - P_0}{P_0(t_1 - t_0)} = \frac{72 - 67.78}{67.78 \times (290 - 273)} = 3.66 \times 10^{-3} C^{-1}$$

Example (6):
A capillary glass tube has a closed end which contains a trapped air column of length 15cm. at 27^{o}c., when the tube is placed in hot oil, then the length of air column .because 20cm. Find the temperature of oil on Celsius scale.
Solution

$$\frac{V_{ol1}}{V_{ol2}} = \frac{T_1}{T_2}, \quad \frac{0.15}{0.20} = \frac{273 + 27}{T_2}$$

$T_2 = 400^{o}k$
The oil temperature $t_2 = T_2 - 273 = 400 - 273 = 127^{o}C$

Example (7):
The bulb of Jolly's apparatus is placed in water vapor at $100^{o}C$. It is notice that the mercury surface in the opened branch rises 10cm over the mercury surface in the second branch. When the bulb is placed in a furnace, it is notice that the mercury surface in the opened branch rises 95cm over the mercury surface in the second branch. If the atm. Pressure is 75cm.Hg calculate the temperature of the furnace.
.
Solution

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}, \quad \frac{(0.75 + 0.1)}{(0.75 + 0.95)} = \frac{100 + 273}{T_2}$$

Therefore, $T_2 = 746^{o}k = 746 - 273 = 473^{o}C$

Example (8):
A balloon of thin rubber wall, which has maximum capacity 1000 cm^3. A quantity of a gas is entered inside it under pressure 73cm-Hg and temperature $6^{o}C$, then its volume becomes $900cm^3$. If the balloon is placed under an evacuated bell jar, and the pressure inside the bell jar decreases to 70 cm-Hg, and the temperature increases to $21^{o}C$ does the balloon explode?
Solution

$$\frac{P_1 V_{ol1}}{T_1} = \frac{P_2 V_{ol2}}{T_2}, \quad \frac{0.73 \times 900 \times 10^{-6}}{(273 + 6)} = \frac{0.7 \times V_{ol2}}{(273 + 21)}$$

Therefore, $V_{ol2} = 989.03 \times 10^{-6} m^3 = 989.03 cm^3$, the balloon doesn't explode.

Example (9):
If the mole of gas occupies volume 22.4L at (S.T.P.), calculate the value of universal gas constant.

Solution

The gas at S.T.P.

$P = 1.013 \times 10^5\ N/m^2$, $T = 273^o k$

$V_{ol} = 22.4 \times 10^{-3}\ m^3$, $n = 1$ mole

From general gas law

$PV_{ol} = n\ R\ T$

Therefore

$$R = \frac{PV_{ol}}{nT} = \frac{1.013\ \times\ 10^5\ \times\ 22.4\ \times 10^{-3}}{1\ \times\ 273} =\ 8.31\ \mathrm{J/moleok}$$

Example (10):
An air bubble rises from the bottom of a lake (at temp. 4^oC) to the surface of water (at temp. 31.7^oC), then its volume becomes $7.7 cm^3$, calculate its volume at the bottom of the lake. If the depth of the lake is 13.6 m, Pa = 75cm.Hg.

$\rho_w = 1000 kg/m^3$, $\rho_{Hg} = 13600 kg/m^3$

Solution

The pressure of water

$P_w = \rho_w\ g\ h_w = 1000 \times 10 \times 13.6$

$= 136000 N/m^2$.

The total pressure (P_1) at the bottom of the lake

$= P_w + P_a$

$= 136000 + 13600 \times 10 \times 0.75$

$= 238000 N/m^2$

from general gas law.

$$\frac{P_1 V_{ol1}}{T_1} = \frac{P_2 V_{ol2}}{T_2},\quad \frac{238000\ \times V_{ol1}}{(4\ +\ 273)} = \frac{102000\ \times 7.7}{(31.7\ +\ 273)}$$

$V_{ol} = 3 cm^3 = 3 \times 10^{-6} m^3$

Example (11):
A container contains 5gram from air under pressure 75cm-Hg, and temperature 27°C the container is opened , and the pressure inside it changes to 72cm-Hg, and temperature becomes 87°C. Calculate the ratio between the leakage gas to the rest gas in the container.

Solution

$\frac{P_1}{m_1 T_1} = \frac{P_1}{m_1 T_1}$, $\frac{75}{5\times300} = \frac{P_1}{m_1\times360}$, $m_2 = 4gm$

the mass of the leakage air = 5 – 4 = 1gm

the ratio = ¼ × 100 = 25%.

Example (12):
An amount of oxygen under pressure 75cm-Hg is mixed with 16 liter of Nitrogen under pressure 76cm-Hg and each of them at 27°C, and the mixture is placed in a closed container of capacity 20L and temperature 30°C. Calculate the pressure of mixture.

Solution

$\frac{PV_{ol}}{T}(mix) = \frac{P_1 V_{ol1}}{T_1} + \frac{P_2 V_{ol2}}{T_2}$, $\frac{P\times 20}{(30+273)} = \frac{75\times 8}{(27+273)} + \frac{76\times 16}{27\times 273}$

P × 0.066 = 2+4.1

P = 91.71 cm-Hg.